New Design of An Intelligent, Secure and Dependable Garage system.

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Abstract*: This work introduces the design and development plan of a reliable, smart, secure, automation solution, applying modern design methodology, for solving real-life problems faced by many residents and related to the process of car parking inside a home garage, as well as, security and economy issues. The suggested solution is intended for achieving comfort, security and economy as a part of home automation. The solution consists of two main subsystems; security identification subsystem and the automated garage subsystem. The security identification subsystem is suggested to be placed inside the car on front tableau. The two subsystems are communicating with each other wirelessly, the whole automated garage system are activated from sleep mode and waiting for further actions, when a vehicle or a human is detected in the front of the gate by means of two sensors, or when identification signal is send from security identification subsystem. For maximum reliability and depending on customer needs, the security subsystem is designed to identify the residents, to have a permission to enter the garage by matching all of the following; face image, fingerprint, voice print, written password, specified oral password word, specially designed remote control board or radio frequency identification (RFID) card along with a alarm features. When the residents identified, the garage subsystem is activated in terms of controlling the garage gate open/close process and controlling electrical components including lighting, ventilation and surveillance camera. Each of the two subsystems, as well as overall system, was physically prototyped, tested in real situation successfully.

Keywords: Design, Smart system, Garage system, Automation system, Security, Safety.

I. INTRODUCTION

Recently, there is a high demand for the new improved designs for intelligent, secure and automated home garage system. That is for providing security, safety, and comfort, including reducing problems that arise when parking i.e., difficulties and disorder of parking. All of this can be achieved by integrating advances in control, sensors, and identification technologies (IT) for controlling the garage gate with minimum human effort, as well as, secure resident, residences and cars.

1.2 Literature review

Home garage automation system is very important in our homes. New improved designs of home garage security and automation system have been investigated for the last decade. Different related scientific issues and design work in the field of home automation related to the smart garage system can be found in the literature [1-4]. In [1] authors present the design of an automated secure garage system using license plate recognition technique (LPR). Optical Character Recognition (OCR) is applied to carry out the LPR. The system allows only predefined vehicles to enter the garage while blocking the others along with a central-alarm feature.

Personal Smart Garage system is implemented in [2], to establish a secured garage system, the card swapping method was implemented and field-programmable gate array (FPGA) is used as main control unit. The security is achieved by reading the plate number. Radio-frequency identification (RFID) is used to provide automatic door opening for only registered cars. In [4] based on Internet of things (IoT) authors proposed a design of a smart garage system which is improved, efficient and high security system. The system allows the resident to control the garage door as well as monitoring vehicles. Moreover, the system can track vehicles which enable the user to track the vehicles inside and outside the garage.

This work introduces a new design of reliable, smart and secured, garage automation system. It introduces the solution for solving real-life problems of the process of car parking inside the home garage. The solution is intended for achieving comfort, security, and economy. The paper is arranged in four sections. Section 2 explains the methodology, literature review of related works and overall systems Structure. Section 3 proposes hardware selection, design, building system prototype, testing, and evaluation. Section 4 demonstrates the results and conclusions.

II. METHODOLOGY, SYSTEM DESIGN, HARDWARE AND INTEGRATION

A. The Design Methodology and concepts

The overall intelligent Garage system is designed for a single bay structure, but the design can be applied for different other garage structure types. The overall system consists of the two main subsystems; automated Garage subsystem, and security subsystem.

The automated garage subsystem consists of the following parts: the control unit, sensors to read states and identify resident, garage gate open/close mechanism, and electrical components including lighting, ventilation, surveillance camera and inner door open/close. While the security subsystem consists of the next components: camera for face scanning, fingerprint scanner, keypad, Microphone, wireless transceivers system, RFID card reader, and control unit. Each of both subsystems' components will be designed, sized and integrated into overall system design.

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The automated garage subsystem is activated when a resident is identified to have authority to enter by matching either any or all applied identification technologies. Depending on garage environment and states (e.g. light level, temperature, and pollution), the electrical components will be switched on/off. The garage gate behavior is be programmed to result in smooth motions without kicks and with minimum both human's effort and interference. The control system, controls the gate's motor to open the door, the motion will keep on until, a sensor (e.g. Limit switch) indicates that the door reached its limits (fully open). When the car is completely parked inside garage, the door similarly gets closed. The garage door will function in similar fashion when owner's car moves out of the garage. In case, an obstacle (e.g. human, child or vehicle) exists in the gate path, the gate motor will stop motion and stand stood, until obstacle is removed.

The security subsystem is designed to identify the residents by matching either or all of the following: face image, fingerprint, voice pattern, password (written password, specified oral password word), wireless programmed remote control board button and RFID card which activates the garage automation system. Security against vandals and thieves is applied by taking video/photo and optionally, switch on sound, light, and buzzer. In this work all the security subsystem will be implemented with all components, to identify residents to activate the garage system. To minimize the power consumption the sleep mode in control algorithm will be enabled. The security system will be activated, when a car existence is detected in the front of garage gate and wait for further decisions/actions.

III. SYSTEM DESIGN AND CRITERIA

Modern concurrent design methodology with synergistic integration is applied for proper subsystems and components parameters design, selection and sizing. The Synergy principles are mainly applied for the right combination of system components and parameters. All sensors are selected to generate a 5VDC signal. The control unit (microcontroller) is powered to read signals and generate 5VDC control signal activate/control drive circuit interfaces that is also powered and activated by 5VDC signal. The placement of subsystems and each of the components in overall system design is explained and pictorially shown at each design stage, as well as, in final overall system integration and system representation.

A. Sensors subsystem selection, design and integration.

Various sensing and data acquiring components are to be applied to detect, measure and monitor various variables in both main subsystems. In the following are introduced the selection, sizing and hardware integration of all these components into overall system design.

Sensors required for the garage system include vehicle existence detection in the front of the garage, motion detection, light level measurement and limit switch/proximity sensing.

For vehicle existence detection inside and in front of garage gate different alternatives are available i.e., proximity, ultrasonic acoustic, infrared magnetic temperature and specially designed sensor utilizing piezoelectric effect. Based on vehicle existence detection, the security and automation subsystems will be activated from sleep mode. For high quality, reliability, vehicle existence detection, and to prevent the interaction and intervention with neighboring system, three types of sensors are selected and designed including :*(a)*NTC temperature non-contact sensor shown in "Fig. 1(a) ", is selected. The sensor is to be placed inside the garage in the front zone, to detect that the car had fully entered inside the garage, up to the safe limit. Moreover, this sensor will be used to monitor the garage environment and activate the ventilation fan.*(b)* digital ultrasonic sensor HC-SR04 shown in "Fig. 1(b)", is selected, it can be applied for accurate non-contact object existence detection. *(c)*the piezoelectric sensor is designed as shown in "Fig. 1(c) ", this sensor is consisting of a strip on which a series of piezoelectric sensors are placed, the strip is placed on the front of the garage gate, based on vehicle load and generated electricity, the vehicle existence is detected.

Obstacles detection sensor for Garage door safety; to detect, if obstacles (e.g. human) exist, in gate pathway when closing or opening**.** Garage door safety sensor circuit consisting of a LDRs and light beam sours (Laser sensor Module) is to be built to be used as emergency shutdown/stop device to stop garage gate motion process while an obstacle exist in its path. Both Laser sensor and the LDR Modules are shown in "Fig. 2*(a, b)",* while the circuit diagram is shown in "Fig. 2(c) ".

Limit approaching sensor: sensor to detect that the garage gate had fully reached the limits of being fully opened or closed. Different options are available including limit switch and magnetic switch both shown in "Fig. 3*(a, b)".*

Sensors for the security system design: The next sensing and recognition devices are required for face, fingerprint, voice, written password (keypad), oral password (Mic.) and RFID card reader, specially designed remote control button board.

Keypad for written password entering, options available, are shown in "Fig. 4*(a, b)", As fingerprint scanner module***,** R307 fingerprint scanner module, shown in "Fig. 4", is selected. *Voice (specified word) recognition for voice control*, the Geeetech® Voice Recognition Module with microphone, shown in "Fig. 5", can recognize as much as 15 voice instruction.

Security access, using radio frequency ident (RFID reader). The RFID-RC522 13.56MHz module reader shown in "Fig.6", is selected. It is highly integrated reader/writer IC, it can only read, in close-range, RFID high frequency tags at 13.56 MHz. *Image capturing,* a suitable choice is VGA OV7670 CMOS camera module shown in "Fig. 7". Specially designed remote-control button board, for specific hexadecimal signal i.e., shown in "Fig. 8".

B. Actuators subsystem selection, design and Integration

Actuators for garage system design: Various actuating devices are applied, including electric motor, Light bulb, ventilation fan, high intensity LEDs, buzzer and alarm siren indicators.

Electric motor is used to open/closed the garage gate, it must size to generate required torque at low speed for specific garage gate mass and shape, motor example is shown in "Fig. 10". It is Lift master K20-5150LD Garage Door Opener Motor for Model MH5011 115V 1P 60Hz [5].

Considering that the garage is built as closed room (shown in "Fig. 9",) with roof and walls, air suction fane for ventilation is used. Ventilation fan example is shown in "Fig. 11".For lighting the garage, at night-time, light bulbs are used. The selected high intensity LEDs, buzzer and alarm siren are shown in "Fig. 12".

Actuators for the security system design; The following actuating devices are required, Light bulb to light the area in the front of the garage door, light and sound alarm indicators (high intensity LEDs, buzzer and alarm siren) to alert residents and neighbors("Fig. 12",).

Wireless communication is used between both main two system parts, the garage and the security parts, three wireless transceivers are used, NRF24L01 2.4GHZ Wireless Transceiver module for Arduino shown in "Fig.13", is selected.

Fig. 1(a) noncontact NTC Temperature

Fig. 1(b) Ultrasonic HC-SR04 Sensor

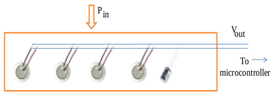

Fig. 1(c) vehicle detection piezoelectric based sensor

Fig. 2(a) LDR module

Fig. 2(b) Laser sensor Module

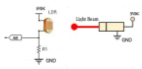

Fig. 2(c) circuit diagram of Garage door safety for obstacles

Fig. 3(a) limit switch

Fig. 3(b)Magnetic switch

Fig. 4(a)(b) Keypad options for password entering

Fig. 5 R307 fingerprint scanner module

Fig. 5Geeetech® Voice recognition

Fig. 6 RFID card reader and tag

Fig. 7 two camera modules; VGA OV7670 CMOS and pi camera

Fig. 8 specially designed button board,

Fig. 9 the garage as a single bay structure

Fig. 10, Garage Door Opener Motor [5]

Fig. 11 ventilation an example

Fig. 12 selected LEDs, buzzer and alarm siren

C. Interfaces signal conditionings and Power supplies

For driving the electric motor, and depending on motor types e.g. AC or DC, different alternatives are available including drive circuit of MOSFETS or relays. Relay 220 AC, 30A (shown in "Fig. 14",) is used, as an interface between control unit and ON/OFF actuators types (Light bulb, ventilation/exhaust fan) to switch it ON/OFF. The circuit diagram of Garage door safety sensor for obstacles is shown in "Fig. 2(c)", up.

Day-night sensor circuit, for switching ON/OFF lights in the garage are built using LDR and voltage divider circuit shown in "Fig. 14(a)". Limit switch is interfaced to microcontroller, using circuit shown in "Fig. 14(b)".

D. Control unit and Control algorithm subsystem selection, design and Integration.

Due to the suggested design consists of two main parts, that communicate wirelessly, and for security consideration, it recommended to utilize two different and separate control units, one for each subsystem.

The proper control unit for the smart garage part, for reading selected sensors and generating control signal is the ATmega2560 microcontroller based MEGA 2560 Arduino board, shown in "Fig. 16(a) ". While a suitable control algorithm for security system is raspberry pi shown in "Fig. 16(b) ", with its capabilities including Tx/Rx transmitter, its built in Wi-Fi and interfacing required by security biometric reading modules. The most proper control algorithm for both main parts is event driven ON/OFF control algorithm.
To minimize the power consumption, sleep mode, in control algorithm, will be applied; the security system will be activated to gather data, when a car existence will be detected in front of garage gate.

Fig. 13 NRF24L01 Wireless Transceiver

Fig. 14 Relay 220 AC, 30A

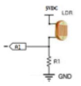

Fig. 15(a) voltage divider circuit

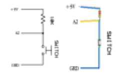

Fig. 15(b) limit switch wiring circuit

Fig. 16(a)the ATmega2560 based MEGA 2560 board

Fig. 16(b) raspberry PI 3+ microcontroller

E. Overall system block diagram representation and components layout

The subsystems and components representation using block diagram are shown in "Fig. 17(a, b, c and d)", in these blockdiagram the two main parts (smart garage and security systems) are further sub classified
into next four parts,

garage subsystem and components, garage gate control subsystem and component, security subsystem and components and vehicle existence detection subsystem and components.

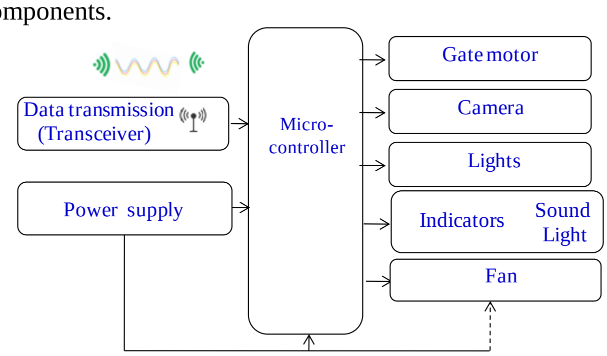

Fig. 17(a), Garage subsystem and components.

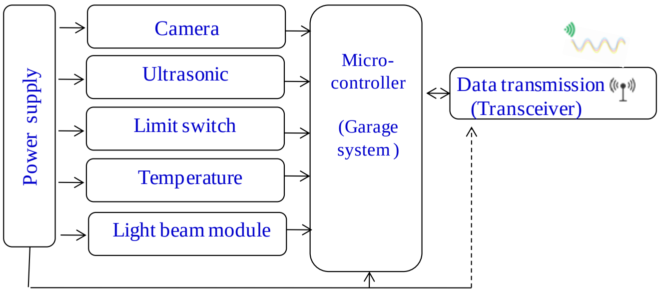

Fig. 17(c), Garage gate control subsystem and components.

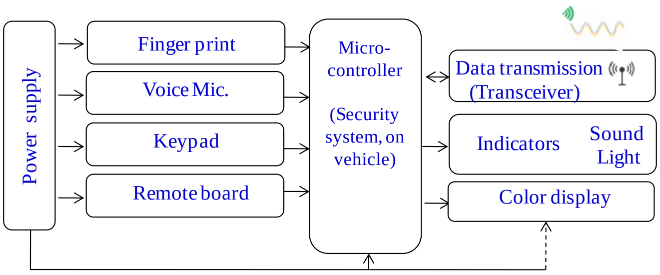

Fig. 17(b), Security subsystem and components (on vehicle)

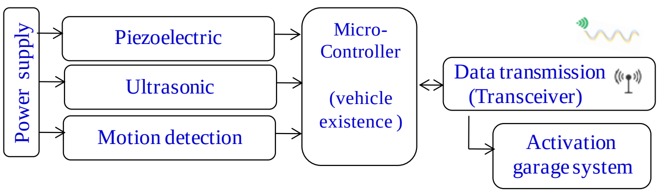

Fig. 17(d) Vehicle existence detection subsystem and components

IV. SYSTEM PROTOTYPING, EXPERIMENTAL TESTING AND EVALUATION

The pictorial representation, of overall system with all designed subsystems and selected components are shown in "Fig. 18".The hardware/software integration and building of all subsystems, as well as, overall smart garage system prototype is built, system and subsystem testing and evaluation for operation, and performance is performed. The testing results show the applicability of the design overall system integration. While testing and evaluating the experimental setup testing, the Arduino IDE monitor is used to display the result of testing.

For experimental testing the part responsible for vehicle existence detection inside and in the front of garage gate(not e.g., a passing human) two sensors circuit was built and applied, infrared magnetic temperature and specially designed sensor utilizing piezoelectric effect. Based on the generated electric voltage of the built piezoelectric based sensor, corresponding to vehicle weight, and detected and read of object temperature by infrared magnetic temperature. The security and automation subsystems will be activated from sleep mode. These settings were tested positive results all the times.

For the garage subsystem sensors, actuators and interface circuits, is connected, interfaces, integrated and experimentally tested. Circuits are designed to detect each of the following *(a)* to detect that the car had fully entered inside the garage, up to the safe limit, using both ultrasonic and infrared magnetic temperature sensors,*(b)* to measure and monitor the garage environment, and*(c)*to monitor the garage gate motion limits (light beam and LDR) and security issues. Building and testing DC motor with drive circuit are shown in "Fig. 19 (b)". Building and testing of wireless transceiver unit, using Arduino d1 mini, to wirelessly transmit reading and signals are shown in "Fig.19 (c)". Building and interfacing LDR and light beam-based safety circuit are shown in "Fig. 19 (*d, e*)".

"Fig. 19 (f)*",* shows testing of car detection, gate open/close motion and safety circuit, while "Fig. 19(g)", shows the physically prototyped, overall garage system with most of components all integrated as one unit. Testing the whole system and each component, result in achieving design goals and device functions as required and designed. Most of components and circuits building and testing procedure are shown in "Fig. 19(*a- g*)".

For the security identification part, in suggested system design, a compact housing module is to be designed and placed inside vehicle e.g. on front Tableau. This housing, depending on selected identification technology, is to encapsulate each or all of the identification components, which wirelessly send identification signal to control unit, and as a result activate the garage system, including gate open/close. The hardware/software integration and testing to identify the residents to have authority to enter are shown in "Fig. 20(*a-i*)". This system is built to identify the residents by matching either or all of the following: fingerprint, voice pattern, password (written password, specified oral password word), wireless programmed remote control board button and RFID card. Based on this activate the garage automation system. Each of these modules and components were interfaced to control unit, separately, tested and evaluated. While, in "Fig. 20(*e ,f*)", are shown the hardware and software integration of security identification part located on top of garage gate, consisting of surveillance camera and include the face image matching. The security subsystem against vandals and thieves is applied by taking video/photo and switching on sound and light buzzers.

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Fig. 18(a)

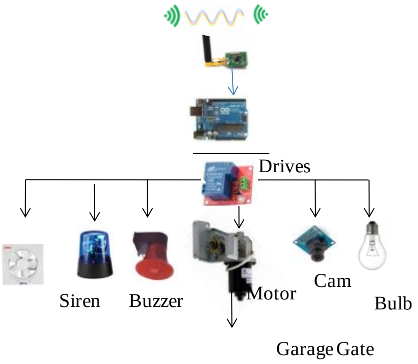

Fig. 18(b)

Fig. 18(a)(b). The overall system pictorial subsystems and components layout/integration diagram.

Fig. 19 (a) Interfacing and testing ; PIR, and MQ smoke, Temperature and light levels sensor

Fig. 19 (b) Building and testing electric motor with drive circuit

Fig. 19 (c) Building, and testing; wireless transceiver unit Arduino Uno d1 mini

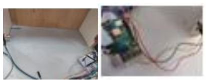

Fig. 19 (d) Testing of LDR/beam based circuit

Fig. 19 (*e*) LDR circuit testing of gate safety circuit

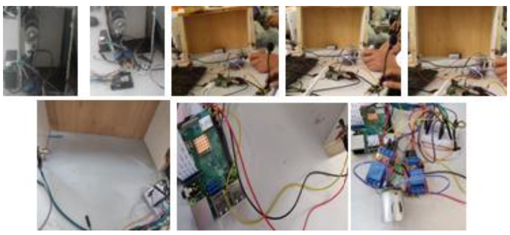

Fig. 19 (f) *S*ubsystems testing ; car detection, gate open/close motion and safety circuit

Fig. 19 (*g*) Overall garage system physically prototyped with most of components all integrated as one

Fig. 20(a) raspberry pi transmitter wiring/testing

Fig. 20 (c) fingerprint sensor wiring/testing

Fig. 20 (e) Voice Recog. Module wiring and testing

Fig. 20(d) Pssword/ Keypad testing

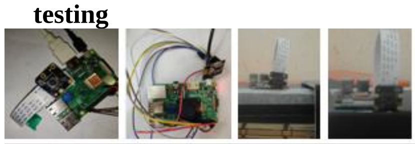

Fig. 20 (f) Camera interfacing to both raspberry and transceiver and testing

V. CONCLUSIONS

The theoretical design, physical development, and testing of an automation solution for solving real-life problems related to the process of car parking inside home garage, as well as, related security and economy issues, was presented and discussed. The developed solution is intended for achieving comfort, security and economy as a part of home automation.

The overall automated garage system, consisting of two subsystems, was physically prototyped, tested and evaluated in real life situations successfully. The security subsystem was, successfully tested to identify resident identity , by each and all of the following; face, fingerprint, voice print, written password, specified oral password word, specially designed remote control board or radio frequency identification (RFID) card. the garage subsystem, was successfully tested in terms of responding to activation signal, and in controlling the garage gate open/close process, ensuring safety issues, and controlling electrical components including lighting, ventilation and surveillance camera.

The testing results show the dependability and applicability of the suggested smart garage system design in achieving comfort, and ensuring security as a part of home automation.

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